

[0149] 1. A method for cleaning a flat media workpiece comprising the steps of:  
forming a boundary layer of a heated liquid on the workpiece;  
providing ozone into the environment around the workpiece; and  
directing a jet liquid through the boundary layer to physically dislodge a  
5 contaminant on the workpiece.

[0150] 2. The method of claim 1 where the liquid comprises water.

[0151] 3. The method of claim 1 where the liquid is pressurized to about 100-  
15,000psi.

10 [0152] 4. The method of claim 1 where the liquid is pressurized to about 400-  
800psi.

[0153] 5. The method of claim 1 further comprising the step of heating the liquid to  
65-99 degrees C..

15 [0154] 6. The method of claim 1 where the ozone is provided as a dry gas into the  
environment around the workpiece.

[0155] 7. The method of claim 1 where the ozone is provided into the environment  
around the workpiece by introducing ozone into the liquid used to form the jet.

[0156] 8. The method of claim 1 further comprising the step of spinning the  
workpiece to help form the boundary layer

20 [0157] 9. The method of claim 2 where the liquid further comprises a member  
selected from the group consisting of hydrofluoric acid, hydrochloric acid, ammonium  
hydroxide, and hydrogen peroxide.

[0158] 10. The method of claim 1 where the liquid comprises a member selected from the group consisting of sulfuric acid, phosphoric acid, and halogenated hydrocarbons.

[0159] 11. The method of claim 1 further comprising the step of irradiating the workpiece with electromagnetic energy.

5 [0160] 12. The method of claim 11 wherein the electromagnetic energy comprises a member selected from the group consisting of ultraviolet , infrared , microwave, gamma or x-ray radiation.

[0161] 13. The method of claim 1 further comprising the step of moving the jet of pressurized liquid relative to the workpiece, so that substantially all areas of the workpiece surface facing the jet are exposed at least momentarily to the jet.

[0162] 14. The method of claim 1 where the jet is perpendicular to the workpiece.

[0163] 15. The method of claim 13 further comprising the step of placing the workpiece within a process chamber.

[0164] 16. The method of claim 8 where the workpiece is rotated at about 100-2000rpm.

[0165] 17. The method of claim 13 further including the step of moving the jet on a swing arm within the chamber.

[0166] 18. The method of claim 1 further comprising the step of introducing sonic energy to the workpiece.

20 [0167] 19. The method of claim 18 where the sonic energy is introduced to the workpiece by a sonic transducer in the chamber and in contact with the workpiece.

[0168] 20. The method of claim 18 where the sonic energy is introduced to the workpiece by introducing sonic energy into a nozzle forming the liquid into the jet.

[0169] 21. The method of claim 1 further comprising the step of cooling the liquid to a temperature below ambient, to increase the density of the liquid and the energy imparted to the workpiece as the jet of liquid contacts the workpiece.

[0170] 22. The method of claim 1 where the jet has a diameter of from about .5-10 mm.

[0171] 23. The method of claim 1 where the workpiece has a top surface and a bottom surface, and where the jet is directed from below against the bottom surface.

[0172] 24. The method of claim 13 where the relative movement occurs at a rate of from about .5 – 500 linear mm per second.

[0173] 25. A method for cleaning a flat workpiece comprising the steps of:  
providing heated liquid onto a surface of the workpiece;  
spinning the workpiece to, at least in part, form the heated liquid into a boundary layer;  
moving a high pressure jet of liquid across the surface of the workpiece, with the jet penetrating through the boundary layer and impacting against the surface of the workpiece, to physically remove a contaminant from the surface; and  
providing ozone around the workpiece, with the ozone diffusing through the boundary layer.

[0174] 26. The method of claim 25 where the ozone is provided by placing the workpiece into a chamber and supplying ozone gas into the chamber.

[0175] 27. The method of claim 25 where the ozone is provided by supplying ozone into the liquid forming the jet.

[0176] 28. The method of claim 25 further comprising heating the workpiece.

[0177] 29. The method of claim 28 where the heating is performed by heating the liquid forming the jet.

[0178] 30. The method of claim 28 where the heating is performed by introducing steam to the workpiece.

5 [0179] 31. An apparatus for removing contaminants from a workpiece comprising:  
a process chamber;  
an ozone source for introducing ozone into the chamber;  
a fixture in the chamber for holding a workpiece;  
at least one jet nozzle in the chamber directed towards the workpiece;  
10 a nozzle driver attached, at least indirectly to the nozzle, for moving the nozzle relative to the workpiece ; and  
a high pressure source of heated liquid connected to the nozzle.

[0180] 32. The apparatus of claim 31 where the high pressure liquid source provides liquid to the nozzle at a pressure of from 500-2000 psi.

15 [0181] 33. The apparatus of claim 31 further including fixture rotor attached to the fixture for rotating the fixture within the chamber.

[00100] 34. The apparatus of claim 31 where the nozzle driver comprises a swing arm supporting the nozzle and an actuator attached to the swing arm.

20 [00101] 35. A method for cleaning a flat media workpiece comprising the steps of:  
forming a boundary layer of a heated liquid on the workpiece;  
providing ozone into the environment around the workpiece, with the ozone diffusing through the boundary layer; and

directing a jet of steam through the boundary layer to physically dislodge a contaminant on the workpiece.

[00102] 36. The method of claim 35 where the boundary layer of heated liquid is formed via condensation of the steam from the jet of steam.

5 [00103] 37. The method of claim 1 where the boundary layer of heated liquid is formed from the jet of liquid.

[00104] 38. An apparatus for removing contaminants from a workpiece comprising:  
a process chamber having an open position, for loading an unloading a workpiece,  
and a closed position, for processing the workpiece, a fixture in the chamber for holding a  
workpiece, a motor for rotating the fixture, at least one jet nozzle in the chamber directed  
10 towards the workpiece, and a nozzle driver attached, at least indirectly to the nozzle, for moving  
the nozzle relative to the workpiece ;

a robot for loading and unloading a workpiece into and out of the process  
chamber;

15 an ozone source for introducing ozone into the process chamber; and

a high pressure source of heated liquid connected to the jet nozzle.

[00105] 39. The method of claim 1 wherein the jet is at an oblique angle to the  
workpiece.